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Volta's Chemical Theories: The First Two Phases

1. Volta and Chemistry

In a letter dated 26 November 1798 from Volta to Martinus van Marum there is a significant passage that deserves quotation:

> J'aime beaucoup la Chymie et surtout la Chymie pneumatique, que j'ai été le premier à cultiver en Italie. Vous devez connaître mes découvertes sur l'air inflammable.[1]

Volta clearly emphasised the outstanding relevance of chemistry and of pneumatic chemistry in his scientific research agenda. However, Volta's chemical investigations have not received much attention from the historians of science and of chemistry.[2] The structure of the two editions of his *Opere* confirms that chemistry was to be considered as a secondary aspect of Volta's scientific programme, which was to be essentially the growth of a physicist.[3] Obviously, it is difficult to give a precise meaning to terms such as "physics", "chemistry", "natural philosophy", because in the age of Volta the experimental sciences did not yet constitute a system of well defined disciplines, with strict boundaries. A thorough contextualization can help the historian define the role of the various branches of natural philosophy in the science of Volta.[4]

In my opinion, a study of Volta's chemical research can shed light on a significant amount of his science and can afford some relevant information about the status of Italian science in the last decades of the eighteenth century. The spread of pneumatic chemistry in the Italian scientific context gave an opportunity for critical revision of the main theoretical tenets and produced a major improvement in empirical research. Thanks to the discoveries of the British aerial philosophers and physicians, Italian science recovered a European dimension. Therefore, I believe that

[1] VOLTA (1798), p. 269.
[2] See: Mieli's Introductions and notes to VOLTA (1928); ABBRI (1995a).
[3] VOLTA (1816) and *VO* (see Abbreviations) contain Volta's papers following a thematic organization, from electromotion to chemistry, and not a chronological one. This approach conceals the fact that Volta made experiments on electricity and chemistry in the same periods. The main anthologies of Volta's writings repeat the model: see for example VOLTA (1967). Only Aldo Mieli emphasized the relevance of Volta's chemistry: see MIELI (1927) and his anthology VOLTA (1928).
[4] STICHWEH (1984).

a real understanding of Volta's chemistry inevitably requires some preliminary information on the introduction of pneumatic research into Italy.[5]

2. Airs and Italian Science

A rough survey of the scientific periodical literature published since 1770 reveals that the Italian scientific community had a huge knowledge of British pneumatics. Hales' *Vegetable Staticks* (1727) deeply influenced Italian science; in the seventies Joseph Black's classic *Experiments upon Magnesia Alba, Quick-lime, and Some Other Alcaline Substances* (1756) and Nicolas Jacquin's *Examen chemicum doctrinae Meyerianae de acido pingui et Blackianae de aere fixo, respectu calcis* (1769) were translated into Italian, and the European debates among the supporters of fixed air and those of *acidum pingue* were known at a very early date. Jacquin's work and Heinrich J. N. von Crantz's *Examinis chemici doctrinae Meyerianae de acido pingui et Blackianae de aere fixo respectu calcis rectificatio* (1770) were reviewed and discussed in Tuscany because the local naturalists were familiar with Austrian culture.[6] From an examination of some Italian journals I have been able to identify the central position of Joseph Priestley's theories and experiments. Priestley's first research in natural philosophy and chemistry attracted immediate attention in Italy. His *Directions for Impregnating Water with Fixed Air* (1772) were translated and published first in Milan in 1773 as a booklet, then in 1774 in the *Raccolta di opuscoli fisico-medici* of Florence, and a résumé of this pamphlet on mineral waters was published in the Florentine *Novelle letterarie* of 1774.[7] In 1773 a translation of Priestley's classic *Observations on Different Kinds of Air* (read in 1772 at the Royal Society of London) was published in the *Giornale dei letterati* of Pisa, and a new edition of this fundamental paper was published in 1774 in Milan.[8] In the Italian journals I have found many translations of Priestley's papers and excerpts of Jacques Gibelin's French edition of his multi-volume *Experiments and Observations on Different Kinds of Air*, which were also translated into Italian in 1784-85 in Naples.[9] Therefore, I can confirm that, until 1784, Priestley exerted a dominating influence on Italian pneumatics.[10] This influence can perhaps explain the scarce attention paid by the Italian scientists to Lavoisier's work.

[5] ABBRI (1989).
[6] ABBRI (1996).
[7] PRIESTLEY (1773); ID. (1774); *Novelle letterarie*, 4 (1774), pp. 36 (columns 574-76), 37 (columns 90-92), 38 (columns 604-7).
[8] PRIESTLEY (1774a); ID. (1773-74).
[9] *Giornale de' letterati*, 24 (1776), pp. 226-41; *Raccolta di opuscoli fisico-medici*, 15 (1777), pp. 39-61; *Novelle letterarie*, 11 (1781), columns 139-42; *Scelta di opuscoli interessanti*, 1 (1775) (reprint 1781), pp. 365-70; 2 (1776) (reprint 1782), pp. 174-6; 3 (1777) (reprint 1784), pp. 64-76, 202-10. PRIESTLEY (1784-85). In the volumes of the Pisa *Giornale de' letterati* from 1778 to 1784 (volumes 31-56) there are the résumés of the French translation of Priestley's volumes both on different kinds of air and relating to various branches of natural philosophy.
[10] On Priestley's influence in Italy and on Volta, see ABBRI (1984).

Lavoisier's *Opuscules physiques et chimiques* (1774) were well known in Italy: Lavoisier sent copies to four Italian scientific societies; excerpts can be found in the periodicals and references in Italian scientific literature.[11] But the Italian chemists concentrated their attention more on the first part – the historical one – than on the second part, containing Lavoisier's original experiments. Only after experimental research on the chemical composition of water did Italian scientific communities become aware of the revolutionary feature of Lavoisier's proposals.[12] Up to 1789 the most influential French chemist was Pierre-Joseph Macquer: his *Élémens de chymie théorique et pratique* (1749-51) were translated into Italian in Florence in 1774 and in Naples in 1782, while the second edition of his *Dictionnaire de chymie* (1778) offered the theoretical framework for a synthesis of a phlogistic theory with the new discoveries on air.[13] In his *Fundamenta chemiae* (1778, 2nd edition) Giovanni Antonio Scopoli, the professor of botany and chemistry at the University of Pavia, accepted Macquer's theory of the calcination of metals. He states that in this chemical reaction the air unites with the metals and phlogiston is released. Scopoli's *Fundamenta* demonstrate the insertion of the new aerial chemistry into the traditional chemical framework.[14]

The fundamental importance of Priestley's ideas and experiments to Italian chemistry can be further stressed by some raw data. For the years 1772-89 I have been able to locate 36 excerpts and translations of Priestley's papers and books, only 3 translations of Lavoisier's *Mémoires* and some general view of the *Mémoires de l'Académie Royale des Sciences de Paris*. We must keep in mind that in Italy French was a more familiar language than English, but in the Italian chemical communities the true adversary of Priestley was Carl Wilhelm Scheele and the debates were among the supporters of the British school and those of the Swedish one.[15]

Priestley was the true instigator of Italian pneumatics and his influence permits us to specify a general feature of the first Italian research in the field of gases. Priestley's discovery of a chemical process to test the goodness of air gave birth to eudiometry, which played a significant role in Italian chemistry and was a significant part of Volta's research. Suffice it to recall that in 1775 Marsilio Landriani in Milan and Felice Fontana in Florence published their works on eudiometry and eudiometrical instruments. Landriani's, Fontana's and Volta's works on eudiometry testify to the lasting link between chemical research, medical and social interests.[16] This link is also an inheritance of the first phases in the establishment of chemistry as a scientific discourse.

[11] LAVOISIER (1957), pp. 409-10, 431-3. *Giornale de' letterati*, 22 (1776), pp. 159-244 contains a long review of Lavoisier's *Opuscules*. "Rapporto ... del primo volume degli Opuscoli fisici ... del Sig. Lavoisier", in *Raccolta di opuscoli fisico-medici*, 4 (1775), pp. 24-54.
[12] BERETTA (1989); ID. (1995); ABBRI (1995).
[13] For Macquer and Italy, see ABBRI (1989), n. 5.
[14] For Scopoli, see ABBRI (1991b).
[15] ABBRI (1991a); ID. (1991).
[16] BERETTA (1995) and his essay in this volume.

From this rough picture of Italian chemistry in the second half of the eighteenth century we can emphasise two general aspects in order to understand Volta's chemistry:

1) Italian savants had wide, up-to-date knowledge of British pneumatic chemistry,
2) Priestley's work exerted a lasting influence on Italian science.

3. Volta's Aerial Chemistry

Not even the most fundamentalist historians of physics would deny the prominent relevance of chemistry in Volta's scientific agenda. However, his theories and experimental research are to be found in letters, papers, notes and manuscripts of his lectures. Excepting the *Lettere sull'aria infiammabile nativa delle paludi*, (1777) Volta never published a systematic work on chemistry though, in a letter to Senebier of December 1777, he announced he was preparing a *Saggio di teorie sulle diverse specie di aria*, which was never published.[17] Examining his papers and letters I have been able to identify three different phases in his chemical thought: the first phase runs from 1776 to 1782; the second emerged in 1783-84: these two phases may be named "phlogistic", while the third one is characterized by Volta's difficult confrontation with Lavoisier's antiphlogistic theory.

Here, I only want to reconstruct the phlogistic phases, which are the most interesting part of his chemical research, to consider the theme of the composition of the various airs, leaving aside his discovery of methane and his devising of the hydrogen eudiometer.

In the first phase, Volta's experimental activities were strongly influenced by Priestley's volumes on *Experiments and Observations on Different Kinds of Air*. This is not surprising, as Priestley was on friendly terms with Volta.[18]

In July 1776 Volta printed in Como a booklet entitled *Proposizioni e sperienze di aerologia*, which is divided into two parts. The first, very short one, is dedicated to the mechanical properties of air; while the second considers the chemical properties of air. This pamphlet reveals Volta's knowledge of the chemistry of air, his large range of sources and his reliance on Priestley for the definition of phlogistication as a fundamental process. Besides Priestley, Volta refers to Boerhaave, Moscati, Fontana, Spallanzani, Lavoisier, Hales, Macbride, Brownrigg, Black, Jacquin, Percival, Landriani, Bergman, Baumé, Pringle, Boyle, but he concludes that:

> Priestley, who in recent years has taken giant steps along this wonderful way, has suggested some very brilliant ideas and views on this subject […], surely we are coming close to an age in which the *Chemistry of air* is going to give birth to a great revolution in natural Science.[19]

I want to call attention to the language and the metaphor used by Volta: physics,

[17] *VO*, VI, p. 252.
[18] See Frederic L. Holmes's essay in this volume.
[19] VOLTA (1776a), p. 62.

chemistry of air, revolution and natural science. He was aware that a new science (the chemistry of air) was born. It was deemed capable of producing a revolution in the whole science of nature and Priestley was perceived as the catalyst of such a revolution.

In a letter to Landriani, dated August 1776, in which Volta made some critical observations on the use of the eudiometer, there are two important statements:

1) the first is linguistic: Volta disliked the term "pneumatologia" because he considered it ambiguous and suggested adopting the term "aerologia" to designate the new branch of chemistry. Afterwards, he used the joint expression "chemistry of air" or "pneumatic chemistry",
2) the second statement is strictly chemical and is one of his first approaches to the problem of the nature of gases. Volta says that fixed air (CO_2) has not got an acid nature, that is: "the acid of fixed air is not essential to this air … [it comes from the acid] … by means of which [this air] is evolved".[20]

In 1776 Volta accepted the idea of the non-acidity of fixed air put forth by Fontana in 1775, but his agreement with Fontana lasted only a few months, because afterwards he read the second volume of Priestley's *Experiments* and modified his views relating to the acidity of fixed air. This volume afforded not only the general concepts, but the style of Volta's research too. The taste for pedant narrative, the Baconian emphasis on the central role of experiment, the theoretical caution so typical of Priestley are significant aspects of Volta's papers and letters. Therefore, it is not unusual to find frequent modifications to his conception of the chemical composition of airs.

In the 4th section of the second volume of his *Experiments* Priestley writes:

> I was now convinced that it was the nitrous acid which the red lead had acquired from the Air, and which had enabled it to yield the dephlogisticated air, agreeable to my original conjecture. Finding also ... that the same kind of air is produced by moistening with the spirit of nitre any kind of earth that is free from phlogiston, and treating it as I had done the red lead in the last mentioned experiment, there remained no doubt in my mind, but that atmospherical air, or the thing that we breathe, consists of the nitrous acid and earth.[21]

This crucial statement is the topic around which, in this first phase, Volta built his aerial theory. The *Terza lettera sull'aria infiammabile* (dated November 1776) reveals his schema of composition of the airs: dephlogisticated air is composed of nitrous acid and earth, inflammable air is air plus strongly combined phlogiston, and phlogisticated air is air plus simple added phlogiston.[22] The central tenet of this schema is the notion that dephlogisticated air can be obtained solely from the calxes impregnated with spirit of nitre. In spite of Landriani's objections to the necessity of the acid for obtaining oxygen, in a letter of July 1777 Volta stated that "the acid of nitre is the true and

[20] *VO*, VI, p. 11.
[21] PRIESTLEY (1776), p. 74.
[22] VOLTA (1776), pp. 36-41.

essential ingredient of respirable air",[23] and this notion was confirmed in the following years. In order to neutralize the numerous objections to it, he was obliged to accept a fundamental tenet of the Stahlian tradition: in nature there is a unique, primitive acid, of which the other acids are modifications.

According to Volta, the production of dephlogisticated air from earths devoid of the acid of nitre did not falsify his theory: the various acids can transmute, therefore the releasing of dephlogisticated air is always linked to the presence of nitrous acid. The influence of the Stahlian tradition on Volta's chemical philosophy can be traced back to his vision of matter too. In a letter to Senebier of November 1777, he states that nature forms natural bodies by different degrees of combination of few elements: firstly, nature combines water and earth, secondly water and fire and then fire and earth. Only after these primitive combinations, combinations of combinations take place.[24] Volta's image of matter is almost identical to that of the French chemistry of the period. The primitive elements are the four Aristotelian principles, the other bodies are mixes and compounds.

In 1777 and 1778 Volta did some experiments combining nitrous air with common air and dephlogisticated air with metallic inflammable air. This second kind of experiments have been considered by those Italian historians interested in priority disputes about the discovery of the compound nature of water. In my opinion, we can ignore priority disputes because they hardly seem crucial. The relevant aspect is Volta's use of analogical arguments in his explanation of combustion of dephlogisticated and inflammable airs. As a matter of fact, an examination of his experiments and reports – above all a letter dated January 1778 he addressed to Priestley – demonstrates that Volta considered the combustion of oxygen and hydrogen as a phenomenon analogous to the volumetric reduction of common air by nitrous air.[25]

In a letter to Landriani of July 1777 he wrote that during the combustion of dephlogisticated air with inflammable air the same reduction in volume takes place as in the combination of nitrous air with dephlogisticated air: the first chemical process was considered a combustion with light, the second one a dark combustion.[26] These different chemical reactions were seen by Volta as the same chemical process of volumetric reduction. Furthermore, this interpretation, based on analogy, helped confirm his theory of the composition of the different airs. In the above-mentioned chemical processes, inflammable and nitrous airs transferred their phlogiston to dephlogisticated air, which lost part of its volume: the differences in the effects observed were due to the different kinds of air used for phlogisticating the dephlogisticated air. Inflammable air consisted in phlogiston plus the acid used to obtain it, while nitrous air was phlogiston plus the acid of nitre. The differences between these two gases were ascribed to the different ways of combining phlogiston with the acid, so Volta could confirm his belief in the existence of a primitive acid.

[23] *VO*, VI, p. 164.
[24] *VO*, VI, p. 247.
[25] VOLTA (1778), pp. 199-206.
[26] *VO*, VI, p. 160.

His failure to isolate water was theoretical: he considered the various airs as particular modifications of the primitive acid carried out by phlogiston. He failed to consider gases as specific chemical substances because his conception of matter enabled him to admit only few elements and the chemical changes were caused above all by phlogiston. This protean substance could explain both the individual features of the airs and their relationships.

4. Phlogiston and the Various Airs

Let me summarize the second phase of Volta's chemical philosophy. In 1783 Volta prepared some lectures on the "Differenti specie d'arie", in which he stated that Priestley "almost created a new science of the factitious airs".[27] These lectures contain a phenomenological description of the airs, based on phlogiston, but present some new notions too. A comparison with the 1776 booklet gives some hints as to the progress and difficulties of Volta's chemistry. In the last section of these lectures Volta attempted a theory of airs based on the existence of three principles: the salt principle, phlogiston and earth. Dephlogisticated air, now called respirable air, is considered to be a "supercomposition" of an acid air already composed of the salt principle, phlogiston and earth. Fixed air and inflammable air have the same principles as respirable air but in different proportions. In fixed air there is less earth and more phlogiston. Of course, Volta was not able to establish the nature and composition of phlogisticated air, which is considered as a product, viz. common air minus its portion of respirable air.[28]

In 1783 and 1784 Volta fundamentally modified his conceptions of the chemical composition of airs. His new aerial theory was influenced by Richard Kirwan's research on the composition of fixed air and its role in the reduction of metallic calxes, and by Priestley's experiments on metallic reduction in a milieu containing inflammable air.

In a letter to Wedgwood of March 1782 Priestley wrote that "what we called Phlogiston is the same thing with inflammable air in a state of combination with other bodies".[29] Priestley promptly informed Landriani of his conclusions and Landriani published in the *Opuscoli scelti sulle scienze e sulle arti* of Milan two of Priestley's letters about metallic reduction in hydrogen.[30] Landriani informed the Italian scientific communities of the new trend in Priestley's research. For example, in issue 44 (May 1782) of the journal *Antologia romana*, a note is published which points out that Landriani acquainted a professor of the *Collegio Romano* with Priestley's experiments.[31]

In 1782 Kirwan informed Priestley that he had identified phlogiston and inflammable air and considered fixed air as a compound of phlogiston and

[27] VOLTA (1783), p. 333.
[28] *Ibid.*, pp. 342-3.
[29] PRIESTLEY (1966), pp. 205-6.
[30] PRIESTLEY (1782); ID. (1782a).
[31] *Antologia romana*, 44 (May 1781).

dephlogisticated air. At first Priestley was sceptical of Kirwan's theory, but in a short time he became a supporter of it. In a letter to Wedgwood of September 1782 he writes that "the late sunshine ... has given me an opportunity of ascertaining beyond all doubts the identity of phlogiston and inflammable air", and in a letter of March 1783 we find: "I have just ascertained by direct experiment what Mr. Kirwan inferred from former ones, viz. that fixed air is a compound of dephlogisticated air and phlogiston or inflammable air".[32] In the second phase Volta's research emerged as a continuation of Kirwan's chemical theory.

In a letter to Senebier dated 21 April 1783 he writes:

> je n'eus pas de difficulté à recevoir la théorie de Mr. Kirwan, que Mr. Priestley a aussi adopté depuis peu, sur la reduction des métaux nobles sans addition [de] phlogistique.[33]

At that time, Volta found an indirect interlocutor: Lavoisier. He was informed of Lavoisier's research but he was not a heretic, so he defended his phlogistic theory by making some adjustments to it.

In 1783 and 1784 Volta's chemical notions can be found in his footnotes to the Italian translation of Macquer's *Dictionnaire de chymie*, edited and translated by Scopoli on the second French edition.[34] Volta's notes give a complete picture of his conceptions of the aerial processes. His concepts are to be found throughout the Italian translated *Dizionario*,[35] from the second to the tenth volume. I will try to summarise them.

Fixed air has a central role in chemical processes: it can be obtained from the transmutation of dephlogisticated air and this is proved by the respiration of animals. In fact, the role of dephlogisticated air is – I quote – "to receive the phlogiston and to combine with it, so that it is transformed into fixed air. This is the core of the question".[36]

At the end of the article "Aria Deflogisticata" Volta puts a long note in two parts dedicated to dephlogisticated and phlogisticated airs in which he sketches his ripe theory. After a short history of the discovery of oxygen (attributed to Priestley), he confirms his thought that dephlogisticated air is produced by nitrous acid. He makes a critical report of Lavoisier's ideas on the composition of nitric acid, but agrees with the French chemist about the existence of an acidifying principle, which, for him, is fixed air.[37]

In bodies, only fixed air exists naturally, not dephlogisticated air. During combustion dephlogisticated air attracts phlogiston, combines with it and by this combination becomes fixed air. Of course, Volta was not able to distinguish carbon dioxide and nitrogen. He states that phlogisticated air has no peculiar properties. Following his image of matter, Volta can establish a sharp difference between an

[32] PRIESTLEY (1966), pp. 212-3, 224-5.
[33] *VO*, VI, p. 315.
[34] See NEVILLE and SMEATON (1981). See also Bernadette Bensaude-Vincent's essay in this volume.
[35] MACQUER (1783-84).
[36] VOLTA (1783a), p. 356.
[37] VOLTA (1783b).

"edotto" and a "prodotto" of a natural process. For him, fixed air is a natural edotto, that is, it really exists in natural bodies, while dephlogisticated and phlogisticated airs are only prodotti (products, results) of chemical reactions. Dephlogisticated, fixed and phlogisticated airs form the links of a continuous chain, but every link has a different natural status. Phlogiston is the common ingredient of all these airs: dephlogisticated air plus phlogiston form fixed air which, combining with phlogiston, forms phlogisticated air. But dephlogisticated and phlogisticated airs can combine with natural bodies only if they are transformed into fixed air. Fixed air is the sole gas which exists in a natural state and which exists by itself. Volta states that fixed air can incline to the two extremes and it is a true Proteus.[38] This statement sounds very ironic when one considers Lavoisier's *Réflexions sur le phlogistique*.

In admitting a main role for fixed air, Volta was aware of Lavoisier's experiments on the reduction of metallic calxes. He does not deny that by the reduction of some calxes (the calx of quicksilver), without the aid of carbon, one obtains dephlogisticated air, not fixed air, but for him during reduction the calx, avid for phlogiston, takes away phlogiston from the fixed air existing in calxes. This air is therefore set free in the form of dephlogisticated air.

In 1783 Volta constructed an original pneumatic theory, influenced by Kirwan and Priestley, even if he did not accept Kirwan's identification of phlogiston with inflammable air, because this air was seen as a combination of phlogiston with an unknown radical.

The notes to the entry "Volatilità" (1784) introduced some novelties into Volta's theory, which were induced by Lavoisier's experiments on the composition of water. Volta immediately became acquainted both with Lavoisier's research and with Priestley's *Experiments relating to Phlogiston and the Seeming Conversion of Water into Air* (read 16 June 1783). He was the first Italian naturalist to consider the crucial topic of the composition of water. In a letter to Landriani (11 December 1783) he claimed his priority in the experiments of combustion of hydrogen and oxygen, but acknowledged he had not seen the water.[39] At the beginning of 1784, Volta attended to the problem of the nature of water, at a much earlier date than other Italian scientists.

It is necessary to give some information on Volta's ideas on water, because in the Italian context the composition of this substance was the theme around which the discussions on the validity of the antiphlogistic theory took place.

Volta did not deny the truth of – his words – Lavoisier's "very fine experiments"; he denied what Lavoisier inferred from them. He suggested a different interpretation based on two tenets:

1) water is an indecomposable substance, devoid of phlogiston,
2) watery vapours, when combined with phlogiston, become permanent gases (Phlogiston is now the principle of volatility and can confer the aerial status).

[38] VOLTA (1783b), p. 373.
[39] *VO*, VI, p. 411.

By pouring water on hot iron, Lavoisier had shown the production of inflammable air. For Volta this fact can be explained by admitting that:

water plus phlogiston make inflammable air.

By the combustion of hydrogen and oxygen one obtains water and perceives the disappearance of oxygen. It follows that this gas contains water, then:

1) inflammable air is water plus phlogiston,
2) dephlogisticated air is water plus "fluido igneo" (fire) which is a different principle from phlogiston.

During the combustion of hydrogen and oxygen a process of decomposition of airs takes place: inflammable air releases phlogiston which combines with the fire of dephlogisticated air and they form flame. The water, originally contained in the two gases, is set free and therefore it can present itself in the form of a liquid.

Volta could then conclude:

1) the composition and decomposition of water are not proved,
2) gases are not elements or simple substances but composite ones,
3) "Mr. Lavoisier's theory necessarily entails the driving away of phlogiston from chemistry, the existence and the roles of which [phlogiston] are established by several other phenomena".[40]

This quotation is revealing. In 1784 Volta was probably one of the first Italian naturalists to be aware of the revolutionary and subversive features of Lavoisier's theory, but he could not accept overthrowing a well-established chemical tradition. His theory was deemed capable of maintaining the continental analytical tradition of chemistry and of explaining the new phenomena of aerial chemistry.

In the subsequent years he raised obstacles against the antiphlogistic theory, but in 1798 he was obliged to acknowledge, without much passion, that "Lavoisier a fixé la vérité".[41]

5. Some Conclusions

In my presentation I have tried to illustrate a few main aspects of Volta's chemical research and to outline the theoretical framework – very fluid indeed – which guided these researches. I have tried to emphasise the influence of British pneumatic chemistry on his thought and on Italian culture.

Let me conclude with two very general considerations.

The first one is methodological. An analysis of Volta's aerial chemistry reveals the mythical character of the so-called theory of phlogiston. In eighteenth-century

[40] VOLTA (1784), p. 105.
[41] VOLTA (1798), p. 271.

chemistry one can discover many different chemical theories in which a particular principle, phlogiston, was used, but the word "phlogiston" referred to different sets of properties. Before Lavoisier, chemistry was an emerging form of knowledge and therefore the chemical revolution cannot be interpreted as a paradigmatic shift from phlogiston to oxygen. Paradigmatic shifts require the existence of well-defined scientific disciplines but, at that time, chemistry had not yet established its disciplinary boundaries. Eighteenth-century chemistry was the arena where various natural philosophers disputed critically their different theories.

My second consideration is simply historical. Notwithstanding their peculiar features, Volta's theories and experiments contributed to the establishment of pneumatic chemical research in Italy. Chemistry had to face many institutional and cultural problems but it became an autonomous science. Together with Landriani's, Fontana's, and the Turin naturalists' works, Volta's research greatly favoured the creation of a new climate for chemistry in Italy, and the Italian scientific communities did not play a minor role in the development of chemistry in the eighteenth century.

Unfortunately, we still lack an exhaustive history of Italian chemistry during the Enlightenment, so hopefully my analysis on Volta can be considered as a contribution to this history.

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